restrial and solar events. On the surface of the sun we observe a synodic period of 26.68 days at the equator, a longer period of 27.30 days at latitude 12°, and still longer periods at higher latitudes approaching 29.50 days near the poles. There is evidence that the period varies also with altitude as well as with latitude. Now, several periods computed in the terrestrial field have been announced to be about 26.00 days—that is, three-fourths of a day shorter than the period observed at the solar equator, which is the smallest period that can be seen on the surface of the sun. Is it probable that at the distance of the earth the angular velocity is much larger than the greatest visible in any part of the photosphere? We may note in regard to the several discussions of this subject that the motion of the atmosphere relative to the surface of the earth, which carries with it the thunderstorms, the aurora, and the electric potential, has not been eliminated from the computed periods. This should be done, and it would result in lengthening the 26.00-day period. Several of these solutions have been executed by least-square methods in one form or another, and the fact that there has been a general failure to come to any agreement as to the true period of the sun's rotation influenced me to employ a simple computation and tabular exhibit of the facts, which would exhibit the periodic events as they occur. On laying down the azimuth angles of the deflecting vectors of the earth's magnetic field in long tables, a marked periodic phenomena became evident, and it persisted through the series of fifteen years over which the work was extended. Now, while it was easy to note the general features of this periodic action and to mark the dates of transition in azimuth, the periodic recurrence was attended in general by an irregular sliding backward and forward through short intervals on both sides of the mean, causing a lap of a day or two on each side of the average periodic time. The actual dates were marked down; an approximate period and epoch were assumed; the system of residuals was determined between the observed and computed dates, and then the adjustment of the assumed period and epoch was made by least squares. It is undoubtedly proper to apply least squares to these data. This unsteady action in the 26.68-day period is like that occurring in the 11-year sun-spot period, which has similar irregularities, some individual periods being longer and some shorter than the average, but from these one can compute the mean period, as Professor Newcomb has recently done by the same least-square process. Now, in the case of the resulting 26.68-day rotation-period there is a further complexity to be considered. The intensity curve is not simple, but it is one having several crests about three days apart, and this shows that the solar output is very unsteady in longitude as well as in latitude. If this curve is developed quite loosely in longitude and the crests move back and forth, as is natural in such a congested struggling medium, then there is a tendency for the crests of the curve in one period to fall upon the corresponding hollows in another period, and thus the maxima and the minima neutralize each other. The result of this fluctuating action is that there is an excessive waste in the summation of the numerical matter, whether by the graphic or the periodogram methods, and the inference that no average period exists is a misapplication of the logical conclusions that should be made. If, then, a fixed period is adopted, and the least-square theorems are rigidly applied as if the events were simply independent and recurring at random, a negative result will certainly be obtained.

Hence, it is evident that one should be very cautious in the application of mathematical analysis to the observations of solar physics generally, and, without such caution, negative results will have very little critical value. It may be well to point out in this connection that the 11-year period of solar-spot formation is confined to the middle latitudes of the sun, from +35° to —35°, and that both polar regions are quite free from this special periodic phenomenon. This result was obtained from the discussion of the Italian observations on the solar prominences, which in the middle zones have the same 11-year period as the spots and the faculæ, but do not continue with this period into the polar latitudes. That fact suggests that too much emphasis may have been laid upon the 11-year synchronism in discussing these solar-terrestrial problems. On the other hand, I have found a 3-year cyclic recurrence which is more characteristic of the entire surface of the sun, and this short cycle has been shown to exist simultaneously in the terrestrial magnetic field, also, in the pressure and temperature variations, and hence in the circulation of the atmosphere generally. It is quite likely that we shall find in this short cycle more evidence of synchronism between solar and terrestrial events than in any other period that has been examined.

In conclusion, we may observe that profound mathematical analysis does not guarantee that the simple law inherent in the physical conditions observed has been secured. There are enough failures of that kind to make one suspicious, because it often happens that the mathematical symbolic language of the equations obscures the implied thought, which is in itself simple, such as might first be brought out by graphical methods. Also, it is evident that negative results have very inferior weight when they proceed from intricate discussions, if the observations naturally bear another interpretation, for the unsuspected secrets of nature still contain surprises to man's inquiring reason.

## TORNADO IN EASTERN ALABAMA, MARCH 20, 1905.

By FRANK P. CHAFFEE, Section Director, Montgomery, Ala.

The tornado was first felt about 6:20 p. m. (seventy-fifth meridian time) of the 20th, at Doublehead, in the northern portion of Chambers County, where one frame building was demolished, one person killed, and two severely injured. The storm crossed the track of the Central of Georgia Railway about two miles north of Welsh, near a settlement known as Bacon Level, where several frame houses were destroyed and four persons seriously injured. A few miles farther east, on Wilson's Plantation, ten people were seriously injured and one frame house demolished; on Holley's Plantation, in the same vicinity, a frame house was blown down and an entire family, consisting of seven persons, was killed and two persons were seriously injured. From this point the storm curved northward to Lime, Randolph County, where several frame buildings were destroyed, and two persons were fatally injured. The storm then passed off northeast into Heard County, Georgia.

The tornado occurred in the southeast quadrant of a general storm eddy, which moved northeastward across northern Alabama on the afternoon of the 20th. It lasted but a few minutes; its path, which extended from southwest to northeast, was about eighteen miles long and varied in width from 75 to 200 yards. It is reported that a well-defined funnel-shaped cloud was observed, which had a bounding motion and which seemed to contract as it struck the ground at points of greatest destruction, the cloud swelling each time it left the ground. A crackling, rumbling noise was heard from the cloud, around which bright, but not particularly vivid, lightning played. In the center of the path débris was carried forward, while on the outer edges much of it was carried in the opposite direction. The funnel-shaped cloud was very dark, and was accompanied by a heavy downpour of rain, the latter lasting about ten minutes.

At Montgomery, about 72 miles southeast of where the tornado started, warm, unsettled weather prevailed during the afternoon of the 20th, with a maximum wind velocity of 22 miles per hour from the southwest.

Total number of persons killed along the storm's path, 9; fatally injured, 2; seriously injured, 18; estimated damage to buildings, timber, and fences, $5000.

The accompanying sketch shows the section of country traversed by the tornado. (See fig. 1.)

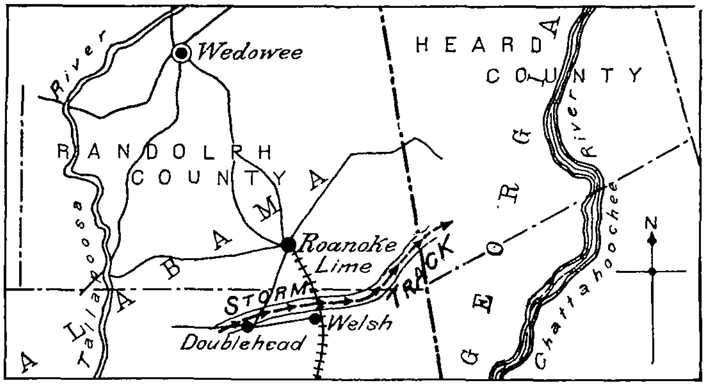


FIG. 1.—Track of tornado in eastern Alabama, March 20, 1905.

## STUDIES ON THE DIURNAL PERIODS IN THE LOWER STRATA OF THE ATMOSPHERE.

### II.—THE DIURNAL PERIODS OF THE BAROMETRIC PRESSURE.

By Prof. FRANK HAGAR BIGELOW.

#### THE STATUS OF THE PROBLEM OF DIURNAL PRESSURE.

The physical relations between the waves of temperature and pressure in the lower strata of the atmosphere, together with their influence upon the electrical and the magnetical fields in the air, have formed subjects of constant investigation during the past forty years, but, unfortunately, without any satisfactory results. In my International Cloud Report, Weather Bureau, 1898, chapter 9, some account of the problem was given, and an attempt was made to throw some additional light upon the subject. The principal point brought out was the fact that there is a very close connection between the variation of the pressure and the magnetic fields over the earth, although I was unable to show what the physical process is which unites them. The papers of this series are supplementary to that investigation, and they show that two important elements have been lacking in the terms of the problem; namely, the variation of the temperature with the height, and the existence of streams of ions or free charges of electricity in the lower atmosphere. Without them it was not possible to explain the connection between the several types of observed phenomena.

There have been in general two lines of attack upon the problem of the coexistence of the single, the double, and the triple barometric waves, as determined by the harmonic components: First, that they are due directly to an effect of the temperature upon the pressure by a change in the density of the lower strata of air; and second, that a dynamic-forced wave is generated chiefly by solar radiation acting in the upper strata of the atmosphere. However, it has not been possible to associate the surface-temperature wave with the semidiurnal and the tridiurnal waves of pressure, because it has been assumed that the surface-temperature wave extends with the same periodic phase into the lower strata. We have shown in the preceding paper that this is not the case, and that there is now sufficient reason for reopening the problem at this place. Regarding the solution by a dynamic-forced wave, it has become more evident[1] from the studies of the absorption of the solar radiation, by means of the bolometer and the actinometer, that the solar energy can not build up temperature and dynamic waves in the upper strata, because the solar radiation is of such short wave lengths as to traverse the earth's atmosphere without general absorption. The outgoing radiation of much longer wave lengths from the earth's surface does, however, suffer absorption, so that such dynamic effects must belong to the lower, rather than to the higher, strata of the atmosphere. Further studies have been made by the Austrian meteorologists, Margules, Hann, and Trabert, in a series of interesting papers[2], since the year 1898.

It may be remarked that these discussions are confined to an account of the double period, apart from its natural combination with the single and triple periods. Suitable periodic variations of the coefficients, in latitude and longitude, were not to be found in the observations at the surface stations, nor at the mountain stations, and there was no data derived from the free air levels. Contact with the ground at low levels, or at high elevations, seems to have destroyed the actual temperature waves found in the free air at 400 meters and upward. It will, no doubt, now be possible to adapt these admirable mathematical studies of the Fourier series, as modified by the deflecting force of the earth's rotation and by friction, to the new temperature data pertaining to the strata up to 3000 meters elevation in the free air.

In order to place before the reader a brief summary of the facts of the barometric pressure waves which are to be explained, the following extract is quoted from my Cloud Report, pages 458, 459.

Analyzing the observed barometric pressure by the harmonic series, $\Delta B = a_1 \sin (A_1 + x) + a_2 \sin (A_2 + 2x) + a_3 \sin (A_3 + 3x)$, and discussing the constant in respect to the observations, it is noted:

1. The normal value of the amplitude of the single daily oscillation $a_1$ is contained within the limits 0.00 and 0.50 mm. It is one-fourth to one-half the amount of $a_2$; its range is wide, being two or three times the normal value; it is very different at neighboring stations, and on the same parallel of latitude; it has greater amplitudes in mountain valleys, but smaller on the seacoast and in higher latitudes; it shows a reversal of phase in the polar regions, also above a certain neutral plane at a given elevation from the ground, produced by interference with the thermic wave; it has a yearly period, with maxima in June in higher latitudes, and in March and September on the equator.

2. The normal value of the phase $A_1$ is near 0°, where $x$ is counted from midnight, and is the hour angle; it varies widely, from 277° to 55°, $a_1$ and $A_1$ must have a general and a local cause. The general cause varies with the latitude and also in the year; the local cause varies with the minor convection currents, and depends upon all the meteorological features which tend to produce local convection.

3. The amplitude of the double daily wave, $a_2$, is the principal term, and covers the limits 0.00 to 1.00 mm. of pressure. Its range is very narrow; it decreases regularly with the height proportionally to the pressure $\frac{B}{760}$; it is very constant over the entire earth up to latitude 55°; it varies with the latitude by a formula which requires an inversion of phase in the polar regions; it has a distinct variation with the year, but exhibits the following peculiarity, namely, that while the maximum insolation is in January at perihelion, the maximum of the semidiurnal wave is at the equinoxes in March and September; also the fact is remarkable that the sun in one hemisphere does not change the amplitude of the wave in the other hemisphere; it combines with the single "thermic" wave, but it is not controlled by it to any appreciable extent; it is smaller on seacoasts, islands, and on mountain tops, and is diminished a little by land and sea breezes; it is very large in mountain valleys.

4. The normal value of the phase of the double diurnal wave $A_2$ is 155°, corresponding to $9^h 50^m$ a. m.; its range is very small, 148° to 163°; it diminishes a little with the height, is retarded to 145° in higher latitudes, varies a little with the year, though in an opposite sense in the two hemispheres, and it is very independent of local meteorological influences.

5. The amplitude of the triple diurnal wave, $a_3$, is a very small quantity, being generally less than 0.10 mm. pressure. It diminishes a little with the latitude; its yearly period is very marked, and has maxima in winter and summer in both hemispheres, with minima at the equinoxes; its maximum is, however, in June, when the earth crosses the sun's equator, and not in July, when the heat is greatest in the Northern Hemisphere.

6. The phase of the triple daily period, $A_3$, has a normal value of 355°, with very small range, and with a small but very well marked yearly period.

[1] See Monthly Weather Review, December 1902, figs. 3 and 4.

[2] Ueber die tägliche Drehung der mittleren Windrichtung und über eine Oscillation der Luftmassen von halbtägiger Periode auf Berggipfeln von 2 bis 4 km. Seehöhe. J. Hann. Wien. 1902.

Same in Meteorologische Zeitschrift. Oktober, November, 1903.

Die Theorie der täglichen Luftdruckschwankung von Margules und die tägliche Oscillation der Luftmassen. W. Trabert. Met. Zeit. November, December, 1903.